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Water Handling Practices and Level of Contamination Between Source and Point-of-Use in Kolladiba Town, Ethiopia

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Abstract

A cross-sectional study was conducted to determine drinking water handling practices and levels of contamination between the source and point-of-use at households in Kolladiba town of Ethiopia. One treatment reservoir, 5 distribution points, and 40 samples of stored water from different households were analyzed for pH, temperature, conductivity, free residual chlorine, total and fecal coliforms. It was found that reservoir was at low sanitary risk score and free from total and fecal coliforms. All the distribution points tested were negative for fecal coliforms and only 2 of them were found positive for total coliforms. Stored drinking water samples were tested positive for total (100%) and fecal coliforms (32.5%). The residual free chlorine in 85% stored water samples was < 0.2 mg/l and in remaining samples it was between 0.2–0.5 mg/l. Low level of residual free chlorine in some distribution points and in majority of the households along with the presence of fecal coliforms in drinking water presents a potential health risk to consumers. Four hundred and sixty two households were selected for data generation by applying cluster sampling. The average consumption of water was 8.2 L/capita/day and in about 88% of the surveyed HHs it was consumed without any home base treatment. Different types of water handling practices like hand washing, cleaning and rinsing of containers prior to collection, covering of filled containers during transportation, drawing water by pouring from storage containers, and keeping of drinking utensils on table after use were recorded and observed during the study period among the participants. Appropriate protection of water reservoir and distribution points in addition to chlorination was found to be necessary for the provision of safe water. The study demonstrated that permanent supply of safe water alone cannot guarantee that water will be safe also for drinking purposes to users at household's level.

Key words: Contamination, drinking water, households, water handling practices, water supply

Introduction

Water is a basic necessity for life. Unfortunately not all water is safe for human consumption. The fact that it is a basic human need and life is not possible without water, forces him to use or even drink water from any contaminated sources which may result to suffering and death from water borne diseases. Therefore, public water supply must be potable, palatable and whole some. Availability of safe water supply and its easy access is a universal need, is essential (African Development Bank, 1999) and is a positive contributing factor to enhance public health and economic development (DFID, 1998). The World Health Organization's (WHO) recognize the human right to water and entitles everyone to have sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses (WHO, 2003). The Target 10 of the United Nations Millennium Development Goals−7 (MDG −7) is to reduce the proportion of people without sustainable access to safe drinking water and proper sanitation to half of its number by 2015 (United Nations, 2005). Currently, about 700 million people in 43 countries are experiencing water stress (UNDP, 2006) and the problem is more prevalent in rural areas (FAO, 2008). Ethiopia suffers from one of the lowest levels of access to water and sanitation in the world, where only 81% of urban and 11% of rural population have access to improved water source and the country lags far behind in achieving MDG−7 (World Bank, 2005; UNICEF, 2006;). Lack of clean drinking water, poor sanitation facilities and lack of community education programs are contributing to continued outbreaks of acute watery diarrhea in some parts of the Ethiopia (USAID, 2007). Worldwide low quality of drinking water and lack of sanitation have resulted in diseases, causing 42,000 deaths every week and over 90% of them occur to children under the age of 5 (WHO/UNICEF, 2005).

In Ethiopia, 60% of current disease burden is attributed to poor sanitation, 15% of total deaths from diarrhea mainly among children under five resulting into some 250,000 children deaths each year (Ministry of Health, Ethiopia, 2005). The most common and wide spread problem associated with drinking water is contamination, either directly or indirectly, by human or animal excreta, industrial and other wastes. Household water often becomes contaminated with pathogens of fecal origin during transport and storage due to unhygienic storage and handling practices (Sobsey, 2002). A systematic meta- analysis of 57 studies measuring bacterial counts for source and stored water in developing countries indicated that bacteriological quality of drinking water significantly declines after collection in many settings (Wright *et al.,* 2004). In Ethiopia, contaminant percolation due to the lack of adequate drainage (Roundy, 1985) and post-source contamination from household containers were reported earlier (Tadesse *et al.,* 2007). Similarly studies carried out in many countries found the extent of recontamination of drinking water after water treatment and during household storage (Brick *et al.*, 2004; Tambekar *et al.,* 2008; Rufener *et al.,* 2010).

Study area

Kolladiba town is situated in North Gondar Zone of Amhara National Regional State of Ethiopia. The town is about 35 km South West from Gondar city with a population of 17,871. The dominant ethnic groups are the Amhara people and the dominant religious group is that of Orthodox Christians, respectively. The water supply in the town is through two boreholes namely *Kederma* and *Gurumba* constructed, respectively in 1980 and 2004. The second borehole starts working only in 2006 however, during the study period only the first borehole was functional. Before pipe water supply i.e. 1980 the town residents were using water from privately owned traditional hand dug wells and from the river *Derema* which passes through the town. During the study period the town water supply was through *Kederma* borehole which is about 94 meter deep and the flow rate is around 11 liter of water/second. Chlorination is carried out in a reservoir and is automatically adjusted to the flow rate of water. After treatment the water is supplied was made to the community through 20 public distribution points (DP). However, the problem related with water handling, collection, transport, storage and finally for consumption in Kolladiba town is not far from the other similar problems in Ethiopia. This study is an attempt to determine water handling practices of households (HHs) and level of contamination caused by these practices in Kolladiba town which are not yet studied. The research hopes to generate more informed and careful exchange of ideas, especially among the key stakeholders in Ethiopia who are in the forefront of policy and program implementation.

Materials and Methods

Sampling Sites and data sets

A cross sectional study was conducted from September 2007 to July 2008 to determine water handling practices and level of contamination between the sources and at point-of-use at Kolladiba town. Cluster and purposive non probability sampling, based on the distance from the treatment reservoir were applied, respectively to select HHs for generating data from the two kebeles (wards) and the study ketenas (sub-wards) of the town. Reservoir fence was found to be broken in some places making it easily accessible for the town residents and thus further increasing the chances of contamination. Distribution points were improperly fenced by wooden poles and iron wire, with poor drainage causing waste water to accumulate nearby. The faucets were not enough to serve the population and distributions points were crowded during water collection. The surrounding areas around the distribution points were not clean and at some points feces were observed near the fence.

Sampling and analytical methods

The methodology used for data generation included questionnaire, observation with checklist and laboratory analysis. Sampling for laboratory analysis was undertaken using recommended procedures of WHO (1985). For analytical study water samples were collected from the reservoir having treatment, distribution points (*bono in Amharic language*) in selected clusters and from the households by applying systematic random sampling technique. For bacteriological analysis samples were collected in sterilized glass stoppered tubes (50 ml.) and in good quality plastic bottles (2 liter) for other physico-chemical parameters. Water sample were collected after sterilizing the taps with ignited cotton wool soaked in alcohol. Eighteen water samples from 5 distribution points and water from treatment reservoir, 120 water samples from 40 household drinking water storage containers were collected aseptically. The water samples were transported to laboratory by maintaining the cold chain system.

Water quality assessment

For the collected samples fecal and total coliform counts were determined with membrane filter method, respectively incubated at temperature of 44 ± 0.5^0C and 37 ± 0.5^0C for 12−16 hours as per the instructions on POTALAB Kit. Residual free chlorine was tested on site by color comparator using N,N-diethyl-p-phenylenediamine (DPD) free reagent. The pH was observed by pH color comparator using wide range pH−4 indicator solution as per Wagtech comparator instruction. Temperature and conductivity were measured with digital thermometer and water proof conductivity meter, respectively. Free residual chlorine, pH and temperature were recorded at site, while fecal and total coliform, and conductivity were carried out in the laboratory. Each parameter was performed in triplicate to get average results. Due to financial constraints and scarcity of laboratory facilities the water analysis was restricted to limited number of samples and parameters.

Set up of questionnaires and interviews

Four hundred and eighty households i.e. 186 HHs from ward-1, sub-ward 3 and 294 HHs from ward-2, sub-ward 1 were selected for survey. A pre-tested, structured self administered questionnaire was used for the data collection. It was prepared in English and translated to Amharic and then back to English to verify the consistency and content of the questionnaire. Data was collected from 462 participants by visiting each house and interviewing women and any other person responsible for the collection of water in the house included. The questionnaires were pre-tested on 10 HHs out of the study sub-wards and the necessary corrections were made accordingly. Completeness and consistency of the collected data was checked at each day of data collection. The quality of data was ensured through training of supervisors and 50 data collectors.

Data assessment regarding socio-demographic characteristics and water handling practices

Data assessment was based upon the socio-demographic (Table 1), water handling and other related practices (Table 2). Observational studies were conducted on water sources and distribution points for the site contamination and physical quality by using sanitary survey forms, recommended by WHO (Lloyd and Helmer, 1991). Data were entered into computer and cleaned. Data analysis was made using the SPSS version 13.0 statistical software. The results were compared with that of WHO (2008) and the Ethiopian drinking water guidelines (Ethiopian Standards, 2001). Daily water consumption was determined from the vessel capacity used for transporting water, number of times water was fetched and the family size of the particular house. Water safety inside the house was determined by observing conditions of water containers and water drawing practices. Sanitary survey of the different sources i.e. borehole, reservoir, distribution points were assessed by using sanitary survey format. The source and the distribution points of water was considered at low, intermediate, high and very high risk score when the sanitary risk score was 0−2/10, 3−5/10, 6−8/10 and 9−10/10, respectively (Lloyd and Helmer, 1991) (Table 3). The water sample with 0 fecal coliform count/100 ml was considered of excellent quality (Grade A), 1−10 colonies/100 ml as acceptable (Grade B), 11−50 colonies/100 ml as unacceptable (Grade C) and >50 colonies/100 ml was considered as grossly polluted (Grade D) (Lloyd and Helmer, 1991). The ethical clearance was obtained from Research and Publication office of the University of Gondar. After the explanation about the purpose of the study, permission was obtained from the offices of Woreda (District) Water Authority, District Municipality and Wards administration. An informed consent was also obtained from the study participants. Anonymity and confidentiality of the information was maintained throughout the data collection process.

Table 1 Socio-demographic characteristics of the study respondents (n=462).

Variables	Respondents	Frequency (%)
Age in years		
< 18	7	1.5
18-30	168	36.4
31-45	182	39.4
46-65	90	19.5
>65	15	3.2
Mean ± S.D	37.38±12.56	
Marital status		
Married	302	65.4
Unmarried	66	14.3
Divorced	40	8.6
Widowed	54	11.7
Education		
Illiterate	184	39.8
Only read and write	81	17.5
1-8 grade	23	5.0
9-10 grade	81	17.5
10/12 grade complete	44	9.5
> 12 grade	49	10.6
Husband education status		
Illiterate	51	16.9
Only read and write	79	26.2
1-8 grade	72	23.8
9-10 grade	13	4.3
10/12 grade complete	41	13.6
> 12 grade	46	15.2
Religion		
Christian	399	86.4
Muslim	63	13.6
Monthly income (in Birr)		
≤ 500	185	40.0
501-999	71	15.4
≥1000	57	12.3
Not disclosed	149	32.3

Results and Discussion

Water quality assessment

Water safety in a community depends on different factors i.e. from the quality of source water to transport, storage and handling practices at household level. Fecal and total coliforms were completely absent in treatment reservoir water. The residual free chlorine, pH and conductivity of the reservoir water were 0.5 mg/l, 7.5 and

680µmhos/cm, respectively. Two out of five distribution points were found to be positive for only total coliforms, while all the five were negative for fecal coliforms. Three distribution points from ward−2 had residual free chlorine less than 0.2 mg/liter, while in remaining from ward−1 it was between 0.2−0.5 mg/l. pH, conductivity and temperature of distribution points water ranged between 6.5-8.5, 680-690 µmhos/cm and 23.3^0C−26.2^0C, respectively. The values of pH, conductivity and temperature of HHs stored water were between 6.5−8.5, 680−700 µmhos/cm and 21^0C−26^0C, respectively. The pH of water at different sources and HHs ranged between 6.5−8.5, which is in accordance with the maximum permissible limit (MPL) of Ethiopian Standards (2001). However, WHO (2008) did not establish any guidelines for pH in drinking water.

Table 2 Water handling practices of households respondents.

Variables	Respondents	Frequency (%)
Type of water collection container		
Plastic bucket	18	3.9
Jerry can	440	95.2
Traditional clay pot (*insra*)	4	0.9
Covering of collection container		
Yes	443	95.9
No	19	4.1
Hand washing before water collection		
Yes	289	62.6
No	173	37.4
Collection container rinsing or washing		
Yes	423	91.6
No	39	8.4
Water storage time period (days)		
< 2	352	76.2
≥ 2	110	23.8
Type of water storage container		
Plastic bucket	138	29.9
Jerry can	208	45.0
Traditional clay pot	110	23.8
Others	6	1.3
Water drawing technique from storage container		
Pouring	258	55.9
Dipping	202	43.7
Others	2	0.4
Placement of drinking utensils		
On the table	348	75.3
Inside the container	47	10.2
Hang on the wall	22	4.8
On the floor	45	9.7

Residual free chlorine in 85 % stored water samples was less than 0.2 mg/l which is not enough to protect extra contamination and in the rest it varied between 0.2−0.5 mg/l. According to WHO (2008) guidelines, residual free chlorine values should be ≥0.5 mg/l, however, in most of the samples it was less than the recommended limit. Residual free chlorine in all distribution points at ward−2 was below 0.2 mg/l, this might be due to their comparatively far distance from the treatment reservoir that eventually increase the cross contamination rate through pipe line. However, the low values of residual chlorine show the inefficiency of disinfection in the distribution system. Water drawing technique and free residual chlorine is found to have statistical association with fecal coliforms (p=0.027). Water having free residual chlorine of <0.2 mg/l, users practicing dipping method and storing water in jerry cans in 38%, 42% and 43% HHs, respectively was found to contaminated with fecal coliforms (Table 4). Trihalomethanes (THMs) were not carried out due to non-availability of equipments and chemicals.

As per the guidelines established by the WHO (2008) and ES (2001), water intended for human consumption should contain no microbiological agents that are pathogenic to humans. However, all the water samples from HHs storage containers were found to be positive for total coliforms, while 32.5% were contaminated with fecal coliforms. Many studies used total coliforms, faecal coliforms or E. coli as an faecal contamination indicator, reflecting available water testing technology in most developing countries (Wright *et al.,* 2004) including Ethiopia. Among these indicator bacteria, E. coli are regarded as the most trustworthy measure of public health risks in drinking water (Edberg *et al.,* 2000). It has been observed that the total and fecal coliforms were more in storage containers water than that from distribution points and reservoir, suggesting that contamination may occur either due to bacterial re-growth (Vanderslice and Briscoe, 1993) or during collection, transport, storage and drawing of water (Wright *et al.,* 2004, Gundry *et al.,* 2006).

Poor sanitation and maintenance and low level of hygiene further accelerate the problem as observed in other Ethiopian studies (Admassu *et al.,* 2004; Tabor et al., 2011). This contamination may lower the health benefits of water source improvements. About 48% of the households have children below 5 years and among this in 64% HHs stored water is easily accessible to children who to draw water without washing hands. Improper handling of water drawing and drinking utensils by children may further contaminate the stored water. Water reservoir and five distribution points were graded as having low sanitary risk score and excellent quality from fecal coliforms point of view (Table 4).

Socio-demographic characteristics

Socio-demographic variables of the study participants showed that the mean (±SD) age of HHs respondents was 37.38±12.56 years. The family size ranged between 1−10 people/HHs with a mean of 4.48 people. Among the total participants, 65% were married and 40% were found to be illiterate. Around 32% of the participants did not disclose their HHs income status. However, average monthly HHs income of the 40% of the respondents was less than 500.00 birr (33.33 $) (Table 1).

About 98.3% of the respondents used protected water sources and in most cases (91%) water is collected by females, while in remaining males were found to perform the task. In most cultures, females are mainly responsible for the collection, use and management of water resources, health and sanitation at the household level (DESA/DSD, 2002). In majority (87%) of the HHs residents, water consumption is less than the basic access of 20 L/capita/day of water for drinking and domestic purposes (WHO, 2003; Howard and Bartram, 2003). Average water consumption in the study area was 8.2 L/capita/day which was lower than that of 12 L/capita/day from Gondar town of Ethiopia (Admassu *et al.,* 2003) as well as from 30–40

L/capita/day from rural areas of most African countries (The Desk and Chair Foundation, 2010).

Water handling practices

In the study area most (95.2%) of the residents use jerry cans while remaining 3.9% and 0.9% use plastic buckets and traditional clay pots (*Insra*), respectively. About 62.6% of the collectors wash their hands before collecting water. Washing and rinsing practice of containers before collection was observed among 91.6% of respondents (Table 2). The currently employed rinsing materials used by the collectors were water, soap or detergent, sand and other materials like grasses and leaves in 29.1%, 46.1%, 24.1%, and 0.7% of the cases respectively. During transport from distribution points to their respective homes, about 96 % of the collectors covered their filled containers. Washing, rinsing and covering of the collection containers practices were found high in the present study as compared with earlier ones from Ethiopia (Zeine, 2005), which may be due to increased awareness of the residents towards these practices. People's behavior has more significance than hardware (containers and layout) in achieving the expected benefits from water supply schemes (Dyer, 2002). Pouring and dipping methods for drawing water from storage containers were used commonly by 55.9%, and 43.7% of the respondents, respectively. Pouring through tilting the vessel or through the use of a clean, special utensil for this purpose only are the safe methods to draw water from containers for use. Water transfer by pouring showed a significant reduction of the concentrations of fecal coliform (Tadesse *et al.,* 2007) as dipping practice increased the risk of contamination by unclean cups and through hand contact (Sobsey, 2002). It was found that most (95.2%) of the respondents used narrowed mouth jerry cans for water collection and storage which are not convenient for drawing water by dipping method.

Table 3 Drinking water quality at point-of-use.

	Fecal coliforms cfu/100 ml					
		0		1-10		
	Households	No	%	No	%	
Residual free chlorine						X^2=4.90
< 0.2 mg/liter	34	21	61.76	13	38.24	P=0.027
0.2-0.5 mg/liter	6	6	100	0	-	
Water drawing techniques						X^2=4.90
Pouring	16	13	81.23	3	18.77	P=0.027
Dipping	24	14	58.33	10	41.67	
Water storage containers						
Plastic bucket	8	6	75.0	2	25.0	
Jerry cans	21	12	57.1	9	42.9	
Traditional clay pot	11	9	81.8	2	18.2	

After use, drinking utensils were mostly kept on table by 75.3% respondents while others left them inside the container, on the floor or hanged it on the wall in 10.2%, 9.7% and 4.8% of the cases, respectively (Table 2). About 51% of the respondents were using separated containers for water storage for drinking and other purposes. The majority (76.2%) of households stored water for < 2 days and from the total households surveyed, algal growth was observed on their water storage and collection containers, respectively in 27.9% and 23.6% cases. Algal growth may be due to inappropriate washing and rinsing system, further creating favorable conditions for micro-organisms growth. Types of storage containers was found to have a strong statistical association with algal growth in the storage container ($P<0.001$).

About 88% of the surveyed HHs consumed water without any home base treatment as most of them (82.7%) believed that the water they used was always clean and safe. May be due to this reason, only in 7.8%, 3%, and 1.5% HHs simple sedimentation, boiling and filtration methods, respectively are in practice before consuming water. Home-based water treatment practices observed in the present study (12.3%) were higher by 4% reported from Gondar, a neighboring town of Kolladiba (Admassu *et al.,* 2003).

Table 4 Sanitary survey and bacteriological quality of reservoir and distribution points (DP).

Ward/sub ward	Water source	Sanitary risk score*	Contamination risk	Fecal coliforms cfu/100 ml	Category	Quality remark on coliforms
01/03	Reservoir	1	Low risk	0	A	Excellent
01/03	DP-1	1	Low risk	0	A	Excellent
01/03	DP-2	0	Low risk	0	A	Excellent
02/01	DP-3	0	Low risk	0	A	Excellent
02/01	DP-4	1	Low risk	0	A	Positive for total coliforms
02/01	DP-5	0	Low risk	0	A	Positive for total coliforms

* Lloyd and Helmer (1919)

Conclusions

The results concluded that awareness and efforts will be required to increase awareness regarding more water use, using pouring or tilting method for drawing water from container, using separate containers for drinking purpose, and home base water treatment in the town. Appropriate protection of water reservoir and distribution points in addition to chlorination was found to be necessary for the provision of safe water. Based on this it can be said that as distance increases from the treatment reservoir the cross contamination rate also increase till distribution points. Absence of residual free chlorine in majority of the HHs and the presence of fecal coliform in drinking water presented a potential health risk to consumers. The concerned authorities should take appropriate measures to maintain residual free chlorine at the distribution points. Unhygienic handling practices at any point between collection and use contributes to the deterioration of drinking water quality in the study area. This study demonstrated that permanent supply of safe water alone cannot guarantee that the water in the household for drinking purpose is safe as well. Proper fencing of the reservoir and distribution points, regular monitoring to ensure the standard residual free chlorine throughout the distribution system and encouraging households to use home based water treatment system may improves the conditions significantly.

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